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December 1963 No. 1097 Vol. 92

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THE METEOROLOGICAL MAGAZINE

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PREDICTION OF THE 24-HOUR DISPLACEMENT OF THERMAL TROUGHS

By G. R. R. BENWELL and G. A. WATT

Summary.—The 24-hour displacement of 1000–500 mb thermal troughs was examined during the period 1960–61 over the sector of the northern hemisphere from the eastern seaboard of America to western Europe. Objective forecasting techniques programmed for use on the computer METEOR were used for selection of the significant parameters for prediction of the latitude and longitude displacement. The best results were achieved by retaining eight parameters for predicting the latitudinal movement and nine parameters for predicting the longitudinal movement in the following 24 hours, with multiple correlation coefficients of 0.75 and 0.67 respectively and root mean square errors of 2.83 degrees of latitude and 4.61 degrees of longitude.

Introduction.—This investigation followed earlier work by Miles and Watt[1] on relaxing thermal troughs and by Miles[2] on amplifying thermal troughs, but it was concerned with the more general problem of predicting the magnitude of the 24-hour latitudinal and longitudinal displacement of thermal troughs. The method followed was to extract values of a large number of parameters for each occasion and to use the objective statistical methods programmed for the METEOR computer by Freeman[3] for selection of the significant parameters. The particular programme used was the multiple non-linear regression programme, also adopted by Moore,[4] which uses the method of least squares to obtain from the data a regression relation of the form:

$$z = a_0 + a_1x_1 + a_2x_1^2 + \ldots . \; b_1x_2 + b_2x_2^2 + \ldots \qquad \ldots(1)$$

The predicand z, in this case, is the latitude (or longitude) displacement of the thermal trough in 24 hours, and x_1, x_2, etc., are the parameters for which values have been extracted. The programme includes a stage for applying significance tests and finally arranges for printing out the requisite coefficients of the regression formula, and also the root mean square error of the predicted values.

The thickness line defining the thermal trough.—For the purpose of this investigation it was necessary to regard each thermal trough as defined by a particular thickness line. This line was chosen so as to extend through the region of strongest thermal gradient in the neighbourhood of the trough line on the initial chart. Subsequent measurements relate to the same line (i.e. the line with the same 1000–500 mb thickness), e.g. the latitudinal and longitudinal displacements of the trough were defined in relation to this line.

Selection of significant parameters.—Details were assembled of 503 thermal troughs during the two-year period 1960–61 and covering the sector of the northern hemisphere from the eastern seaboard of America to western Europe.

Associated synoptic features are shown in Figure 1 along with the abbreviations used in the tables in this paper. Relationships connected with these

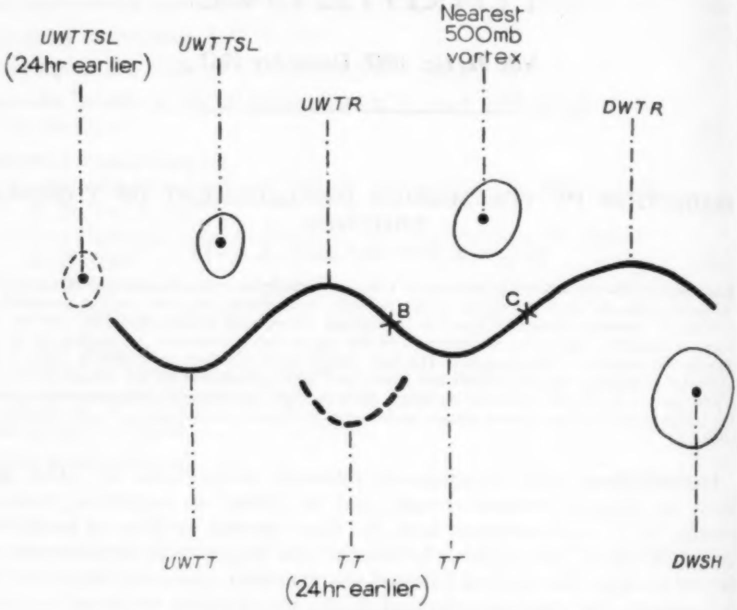

FIGURE 1—SYNOPTIC FEATURES USED IN THE INVESTIGATION

——— Thickness line defining trough
- - - - Thickness line defining trough 24 hours earlier
——— Isopleth delineating surface low, surface high or 500-mb vortex
- - - - Isopleth delineating surface low 24 hours earlier
TT Thermal trough for which prediction is required
UWTT Upwind thermal trough
UWTTSL Upwind thermal trough surface low
UWTR Upwind thermal ridge
DWTR Downwind thermal ridge
DWSH Downwind surface high

B and C are positions used for measurement of 500-mb flow where direction is measured in degrees true, and gradient in decametres per 400 nautical miles.

features were used as parameters in equation (1) for forecasting the movement of the thermal trough. Parameters are listed and numbered in Table I, and in Figures 2 and 3 the parameters found to be the most significant are shown in diagram form.

Various powers of the parameters appear in equation (1), and powers of the parameters up to the sixth were used in the initial work on latitude prediction. It was considered, however, that the size of the sample (503 cases) did

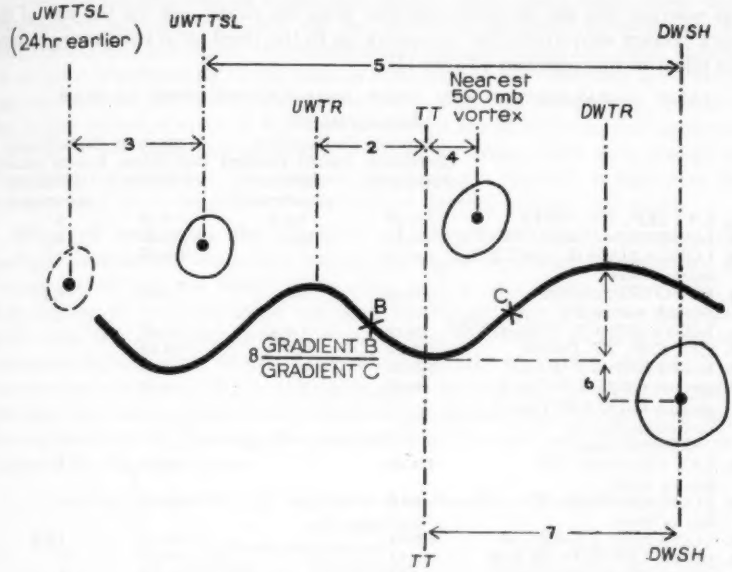

FIGURE 2—LATITUDE PREDICTION: SIGNIFICANT PARAMETERS
Parameters are numbered with reference to Table I. For abbreviations see Figure 1.

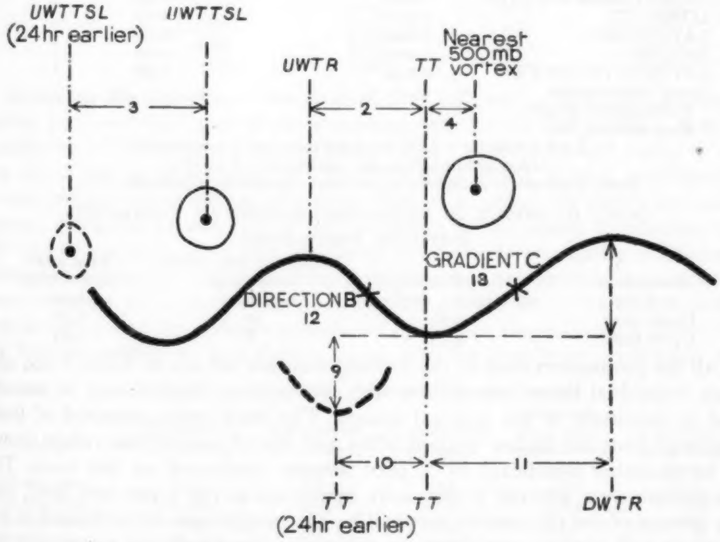

FIGURE 3—LONGITUDE PREDICTION: SIGNIFICANT PARAMETERS
Parameters are numbered with reference to Table I. For abbreviations see Figure 1.

not warrant the use of powers greater than the third, and for the rest of the work powers were restricted to powers up to the third; it is interesting to note the effect of this restraint (Table II).

TABLE I—PARAMETERS AND THEIR CORRELATIONS WITH 24-HOUR DISPLACEMENTS

	Latitude displacement Correlation coefficient	Latitude displacement Powers retained (significant parameters)	Longitude displacement Correlation coefficient	Longitude displacement Powers retained (significant parameters)
1. LAT SEP: *TT–DWTR*	+0.46	1,2,3	−0.11	2
2. LONG SEP: *UWTR–TT*	−0.41	2,3	−0.40	1,3
3. LONG CHANGE: *UWTTSL* last 24 hours	+0.39	2	+0.26	1
4. LONG SEP: nearest 500-mb vortex–*TT*	+0.30	1,2	0.00	1,3
5. LONG SEP: *UWTTSL–DWSH*	−0.12	1,2,3	−0.28	
6. LAT SEP: *TT–DWSH*	+0.22	2,3	−0.26	
7. LONG SEP: *TT–DWSH*	+0.16	1	−0.08	
8. 500-mb GRADIENT at B / 500-mb GRADIENT at C (i.e. confluence or diffluence ratio)	−0.28	1	−0.09	
9. LAT CHANGE: *TT* last 24 hours	+0.22		+0.40	1
10. LONG CHANGE: *TT* last 24 hours	−0.18		+0.25	2
11. LONG SEP: *TT–DWTR*	+0.04		+0.17	1,2,3
12. 500-mb DIRECTION at B	−0.14		−0.37	2
13. 500-mb GRADIENT at C	+0.17		+0.24	2
14. 500-mb GRADIENT at B	−0.16		+0.08	
15. LAT SEP: nearest 500-mb vortex–*TT*	+0.31		−0.06	
16. Central pressure *UWTTSL*	−0.04		+0.05	
17. LONG: *TT*	+0.10		+0.12	
18. LAT: *DWSH*	+0.08		−0.11	
19. MONTH	+0.07		0.00	
20. LAT SEP: *TT–DWTR* (using thickness line 6 decametres greater than defining line)	+0.52		−0.08	

LAT=latitude LONG=longitude SEP=separation
Other abbreviations are explained in Figure 1.
Note: Parameters numbered 14–20 were rejected by significance test.

TABLE II—EFFECT OF RESTRICTING POWERS OF PARAMETERS (LATITUDE PREDICTION)

Restriction in powers	Highest multiple correlation coefficient	Number of parameters retained as significant	Root mean square error *degrees*
Up to sixth	0.77	10	2.70
Up to third	0.75	8	2.83

All the parameters used in the investigation are set out in Table I and also their individual linear correlations with the 24-hour displacement in latitude and in longitude of the thermal trough. The parameters consisted of those suggested from the earlier work of Miles and Watt,[1] and of those others shown to be probably significant by a pilot scheme conducted on 300 cases. The parameters were selected if they were significant at the 5 per cent level, and the powers of the parameters retained by the programme are indicated in the table. It will also be seen from the table that the significant parameters for prediction are not necessarily those with the highest individual linear correlation coefficients.

Other parameters such as vorticity or Rossby wave speed might have been incorporated into the work, but the fact that meteorological variables are not independent and are closely correlated means that, provided the initial number of variables is sufficiently large, there is little ground for expecting appreciable improvement by extending the number of parameters indefinitely. Probably the largest source of error in this kind of work is found in the initial conditions when, as in this work, information is required for areas where data are sparse; experience suggests that the error in positioning a thermal trough over the Atlantic must be of the order of two or three degrees on many occasions.

Effect of reducing the number of significant parameters.—The multiple correlation coefficient using the eight significant parameters for latitude prediction was found to be 0.75, with a root mean square error of 2.83 degrees of latitude; using the nine significant parameters for longitude prediction, the multiple correlation coefficient was found to be 0.67 with a root mean square error of 4.61 degrees of longitude. The effect of using fewer parameters is shown in Table III which gives the multiple correlation coefficients and root mean square errors obtained for smaller sets of parameters. Each set was obtained by choosing the parameters so that the best combination was obtained for that size of set.

TABLE III—EFFECT OF REDUCING THE NUMBER OF SIGNIFICANT PARAMETERS

Number of parameters	Latitude displacement: Multiple correlation coefficient	Latitude displacement: Root mean square error *degrees*	Longitude displacement: Multiple correlation coefficient	Longitude displacement: Root mean square error *degrees*
9	—	—	0.67	4.61
8	0.75	2.83	0.65	4.73
7	0.72	2.94	0.64	4.77
6	0.70	3.04	0.63	4.82
5	0.67	3.14	0.61	4.92
4	0.66	3.18	0.57	5.11
3	0.64	3.26	0.54	5.26

Checking the results.—The method often followed in this form of investigation is to use only a part of the assembled data for the first analysis, then to modify the results by incorporating a second part of the data and finally to use the rest of the assembled data in a check of the method. In this investigation it was decided to use all the assembled data in selecting the significant parameters; to obtain an estimate of the variability of the results in practice, the 503 cases were split in various ways and the multiple correlation coefficients and root mean square errors resulting from the use of the significant parameters were obtained for each sample. These results are shown in Table IV and it will be noted that the multiple correlation coefficient ranged from 0.68 to 0.80 for latitude prediction and from 0.63 to 0.70 for longitude prediction: the

TABLE IV—VARIATION WITHIN THE 503 CASES

Sample	Latitude: Correlation coefficient	Latitude: Root mean square error *degrees*	Longitude: Correlation coefficient	Longitude: Root mean square error *degrees*	Mean change in 24 hours *degrees*
First 250 cases	0.72	2.85	0.67	4.36	11.3
Last 253 cases	0.80	2.63	0.68	4.64	13.4
First 150 cases	0.68	3.15	0.63	4.16	11.3
Last 353 cases	0.79	2.62	0.70	4.65	12.9
Cases in 1960	0.73	2.82	0.69	4.42	11.8
Cases in 1961	0.80	2.63	0.68	4.62	13.4

appropriate range of the root mean square errors was from 3.15 to 2.62 degrees for latitude prediction and from 4.16 to 4.65 degrees for longitude prediction.

The root mean square errors in the longitude prediction suggest that the samples concerned were different in character, and the measure of the mean longitudinal movement of the troughs in the different samples should also be considered. It appears that the errors are smaller for the groups in which the mean change in longitude is smaller.

It might be advisable to point out that in the latitude band 40°–60°N, 4.6 degrees of longitude is equivalent to about the same distance as 3.3 degrees of latitude. Thus the disparity between root mean square errors for latitude and longitude is not as large as at first appears.

Forecasting.—Tables V and VI may be used for forecasting; in practice the values of each of the various significant parameters would be written down after selecting the defining thickness line (the thickness line centred through

TABLE V—LONGITUDE PREDICTION

Contribution in degrees

Degrees of CHANGE or SEPARATION	LAT SEP: *TT–DWTR*	LONG SEP: *UWTR–TT*	LONG CHANGE: *UWTTSL* last 24 hours	LONG SEP: nearest 500-mb vortex–*TT*	LAT CHANGE: *TT* last 24 hours	LONG CHANGE: *TT* last 24 hours	LONG SEP: *TT–DWTR*	500-mb DIRECTION at B *degrees true*	Contribution in degrees	500-mb GRADIENT at C (decametres per 400 n.miles)	Contribution in degrees
−30				2.2							
−25				2.0							
−20				1.8							
−15				1.4							
−10			−1.4	1.0	−2.4			240	4.3	9	0.3
− 5			−0.7	0.5	−1.2		−2.0	250	3.8	12	0.5
0	5.2		0.0	0.0	0.0	0.0	0.0	260	3.3	15	0.7
5	5.1		0.7	−0.5	1.2	0.1	1.3	270	2.7	18	1.0
10	4.7	5.6	1.4	−1.0	2.4	0.5	2.1	280	2.2	21	1.4
15	4.1	3.5	2.2	−1.4	3.7	1.0	2.5	290	1.6	24	1.9
20	3.3	1.7	2.9	−1.8		1.8	2.7	300	1.0	27	2.3
25	2.2	0.1	3.6	−2.0		2.9	3.0	310	0.4	30	2.9
30	0.9	−1.2	4.3	−2.2		4.1	3.4	320	−0.2	33	3.5
35		−2.1	5.1	−2.2		5.6	4.2	330	−0.9	36	4.1
40		−2.6		−2.1		7.3	5.5	340	−1.5	39	4.9
45		−2.5		−1.8		9.3	7.6	350	−2.2	42	5.7
50				−1.4			10.6	360	−2.9	45	6.5
55				−0.8							
60				0.2							
65				1.3							
70				2.8							

Northward and eastward displacements and changes in 24 hours are positive; separations are positive if northward or eastward travel is involved in passing from the first mentioned feature to the second. A positive predicted value therefore indicates northward displacement in the case of latitude and eastward displacement in the case of longitude.

Abbreviations are explained in Figure 1 and Table I.

TABLE VI—LATITUDE PREDICTION

Contribution in degrees

Degrees of CHANGE or SEPARATION	LAT SEP: *TT–DWTR*	LONG SEP: *UWTR–TT*	LONG CHANGE: *UWTTSL* last 24 hours	LONG SEP: nearest 500-mb vortex–*TT*	LONG SEP: *UWTTSL–DWSH*	LAT SEP: *TT–DWSH*	LONG SEP: *TT–DWSH*	Confluence or diffluence ratio per cent	Contribution in degrees
–30				–3.7				40	–9.8
–25				–2.9		4.0		45	–9.9
–20				–2.2		2.4		50	–10.0
–15				–1.6		1.2		55	–10.1
–10			0.3	–1.0		0.5		60	–10.2
–5			0.1	–0.5		0.1		65	–10.4
0	0.0		0.0	0.0		0.0	0.0	70	–10.5
5	2.7	–0.2	0.1	0.4		0.1	0.4	75	–10.6
10	4.1	–0.9	0.3	0.7		0.3	0.8	80	–10.7
15	4.8	–1.7	0.6	1.0	5.5	0.6	1.2	85	–10.8
20	5.3	–2.7	1.1	1.2	6.7	0.9	1.6	90	–11.0
25	5.9	–3.6	1.8	1.4	7.7	1.1	2.0	95	–11.1
30	7.1	–4.3	2.6	1.5	8.4	1.2	2.4	100	–11.2
35		–4.8	3.5	1.5	9.0	1.0	2.8	105	–11.3
40		–4.7		1.5	9.3	0.6	3.2	110	–11.4
45		–4.1		1.4	9.4		3.6	115	–11.6
50				1.3	9.4		4.0	120	–11.7
55				1.1	9.3		4.4	125	–11.8
60				0.8	9.0		4.8	130	–11.9
65				0.4	8.6		5.2	135	–12.1
70				0.0	8.1		5.6		
75					7.5		6.0		
80					6.9		6.4		
85					6.3		6.8		
90					5.7				
95					5.1				
100					4.5				
105					4.0				
110					3.6				
115					3.2				
120					3.0				
125					2.8				
130					2.8				
135					3.0				

Northward and eastward displacements and changes in 24 hours are positive; separations are positive if northward or eastward travel is involved in passing from the first mentioned feature to the second. A positive predicted value therefore indicates northward displacement in the case of latitude and eastward displacement in the case of longitude.

Abbreviations are explained in Figure 1 and Table I.

the strongest gradient in the thermal trough). Reference to the appropriate tables would give the contribution to the displacement for each parameter and the sum total would give the predicted displacement.

The convention used for sign in this investigation is that northward and eastward displacements and changes in 24 hours are positive; separations are positive if northward or eastward travel is involved in passing from the first mentioned feature to the second. A positive predicted value therefore indicates northward displacement in the case of latitude and eastward displacement in the case of longitude.

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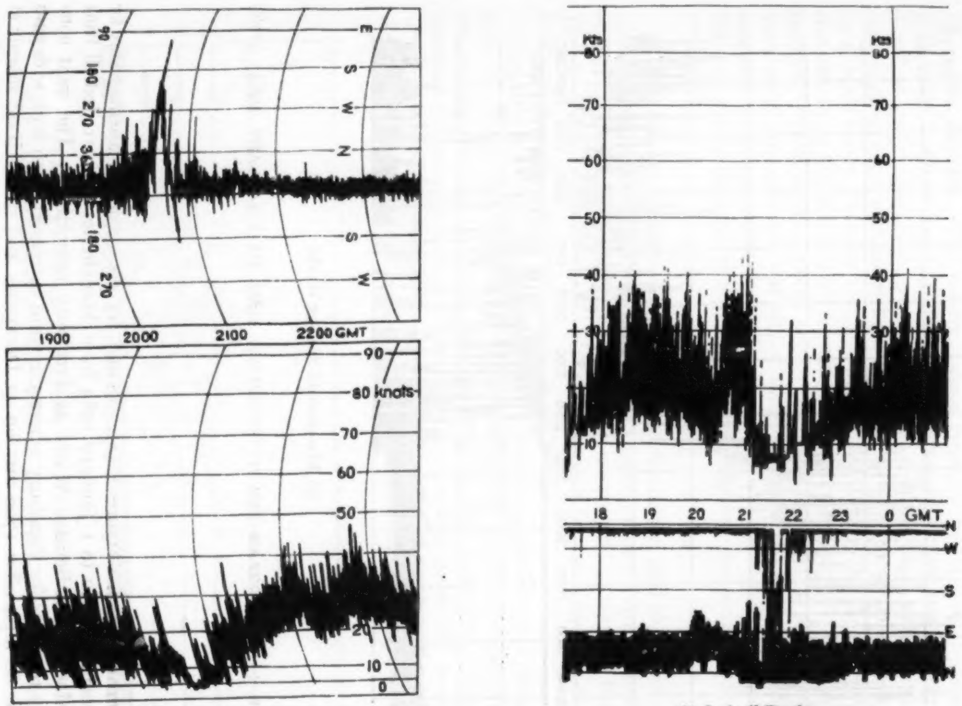
ROTOR STREAMING OVER THE PENNINES

By L. DENT and B. DYSON

A period of unusually severe surface turbulence occurred in east Cheshire on the evening of 31 December 1962 and continued into 2 January 1963. Unpleasant flying conditions were reported near Manchester Airport. At Macclesfield the Cheshire Fire Service received over 300 calls for assistance between these dates to deal with damaged property, ranging from the collapse of chimney stacks and removal of a house roof to uprooted trees, one of which killed a motorist. Calls increased rapidly after 1500 GMT and reached a peak between 2100 and 2200 GMT on New Year's Eve.

Aircraft reports.—Aircraft operating into Manchester Airport reported severe turbulence on 31 December. A BEA Viscount landed at 2035 GMT from London after suddenly encountering violent turbulence at 5500 feet over Congleton. The pilot was lifted from his seat for several seconds, whilst a passenger was flung against the roof of the aircraft and received head injuries. Descending with indicated airspeed of 155 knots, 43 per cent flap, and power off, i.e. throttles back, the aircraft reached 3200 feet only to be lifted back to 4800 feet. The turbulence during descent was described as varying between moderate and violent, the initial impact over Congleton being worst.

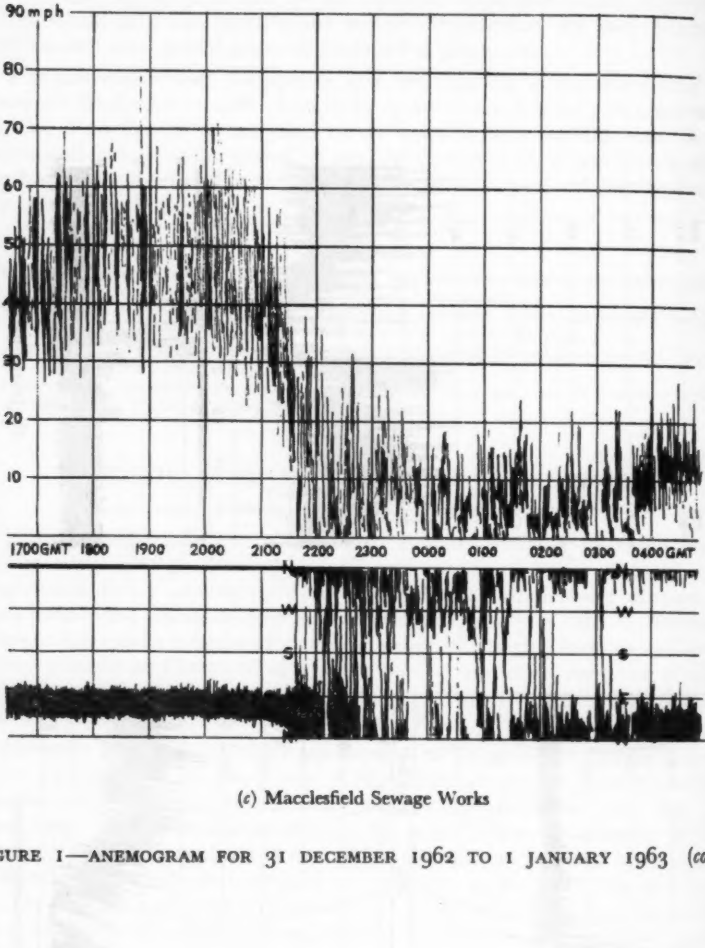
Another BEA Viscount landed at 1920 GMT from Birmingham after meeting severe clear air turbulence over Congleton at 6000 feet. With wheels down and 43 per cent flap, fluctuations in indicated airspeed between 130 and 170 knots were common. At 2000 GMT taking off on runway '06' towards the hills at Oldham, this same aircraft met with only moderate turbulence which ceased above 6000 feet. Route weather at 17,000 feet on this flight between Glasgow and Birmingham was reasonably smooth. Finally landing at 2330 GMT turbulence was again encountered near Congleton, but was less severe than on the previous occasion. There was a little cloud up to 8000 feet on the final flight but no significant cloud earlier. South of Congleton at 6000 feet turbulence was not remarkable.



(a) Manchester Airport

(b) Jodrell Bank

FIGURE 1—ANEMOGRAMS FOR 31 DECEMBER 1962 TO 1 JANUARY 1963



(*c*) Macclesfield Sewage Works

FIGURE 1—ANEMOGRAM FOR 31 DECEMBER 1962 TO 1 JANUARY 1963 (*contd*)

Anemograms.—Figure 1 (*a*), (*b*) and (*c*) are copies of anemograms for 31 December 1962 to 1 January 1963 from Manchester Airport, Jodrell Bank and Macclesfield Sewage Works at Prestbury respectively. The most noteworthy record is for Prestbury where the wind increased to 50 mph with gusts to near 80 mph after 1700 GMT on 31 December and then fell off sharply at 2130 with the sudden onset of a rapidly varying wind direction. This disturbance was maintained until about 1700 GMT, 1 January 1963 after which the gusty easterly wind was resumed. During the first six hours the direction was quite erratic, but after about 0400 it was mainly limited to south-east through north to north-west.

At Manchester Airport the easterly wind was interrupted for a short while at 2030 GMT on 31 December when the speed fell to below 10 knots with a variable direction, and at one point a calm. A similar feature is seen on the Jodrell Bank anemogram about 2115. At Manchester Weather Centre the gusty easterly wind was maintained throughout the night but a noticeable temporary moderation occurred at 1900 GMT.

Synoptic details.—The hourly surface synoptic charts from 1500 GMT on 31 December 1962 to 0001 1 January 1963 represent a strong easterly gradient of 100° at 40–50 knots over northern and central England. Extensive strato-cumulus cloud gave occasional light snow or freezing drizzle in places though not at Manchester. Pressure rose throughout the period of these charts but by 2100 GMT on 31 December a lee trough was forming to the west of the southern Pennines, and at 2300 a small centre could be sketched in to the south of Manchester. An occlusion was almost stationary from Cork to Dorset and was associated with a westerly thermal wind in the 1000–500-millibar layer over England which reduced the strong easterlies below the inversion to light winds aloft.

Rotor streaming.—The severity of the turbulence, and the anemograms together with the wind and temperature data suggest that the strange behaviour of the wind on New Year's Eve was due to rotor streaming over the Pennines. The absence of any supporting visual observations because it was dark makes it difficult to deduce the organization of the rotor.

The phenomenon of wave streaming has been reported from the Isle of Man by F. W. Ward[1] and from Crossfell in Cumberland by G. Manley[2] but there are probably few instrumental records made in rotor streaming. Corby[3] has described this extreme feature of mountain airflow and quotes the work of the Czech glider pilot Förchtgott. Figure 2 is taken from *Meteorological Report No.* 18[3] and illustrates the mechanism. The essential ingredients appear to be

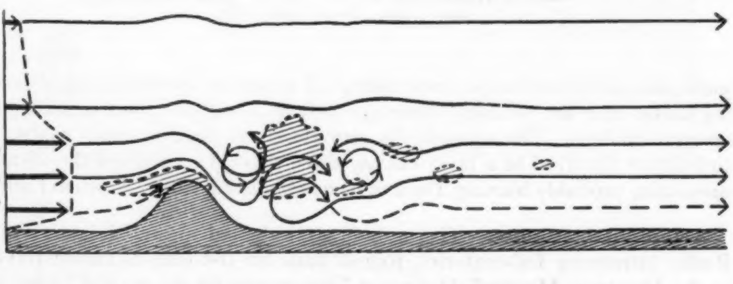


FIGURE 2—ROTOR STREAMING (AFTER FÖRCHTGOTT[3])

'A' indicates streaming layer. Bold arrows on the left show the wind profile.

a strong wind component across the mountain ridge—on the present occasion winds were easterly—together with a reverse wind shear which reduces this component to a low value at some higher level, so providing a streaming layer of limited depth.

An examination of the temperature and wind data for the undisturbed airstream over Hemsby at 1200 GMT on 31 December reveals a marked temperature inversion between 870 and 820 mb above which the 30-knot easterly wind fell off to 12 knots at 800 mb. Figure 3 shows this variation of temperature and wind with height together with the profile of Scorer's parameter l^2. These

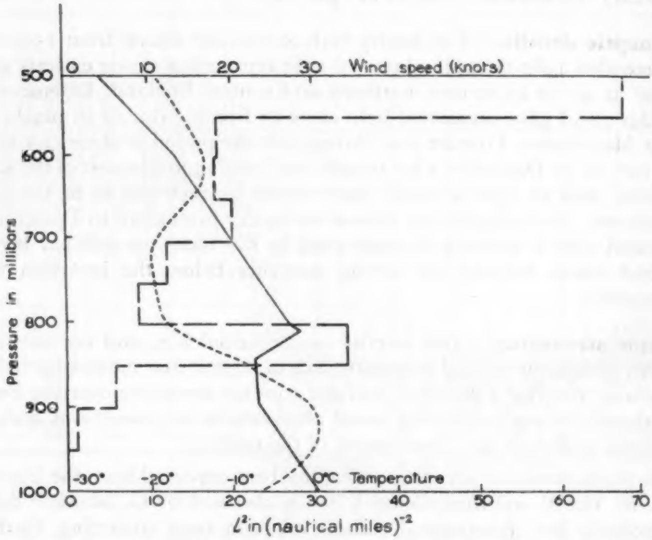


FIGURE 3—TEMPERATURE, WIND DATA AND VALUES OF l^2 FOR HEMSBY AT 1200 GMT ON 31 DECEMBER 1962

——— Temperature in °C - - - wind speed in knots
— — — values of l^2.

particular patterns of wind speed falling off above the inversion and of increasing values of l^2 are precisely those specified by Corby for rotor streaming and severe turbulence. The example fits very closely to the Förchtgott model. The turbulence occurred in a layer exactly three times the height of the offending mountain, probably Shining Tor and its neighbouring ridges shown in Figure 4.

Acknowledgements.—The authors are indebted to the Director, Nuffield Radio Astronomy Laboratories, Jodrell Bank for the loan of Figure 1 (*b*) and to the Manager, Macclesfield Sewage Department for the loan of Figure 1 (*c*).

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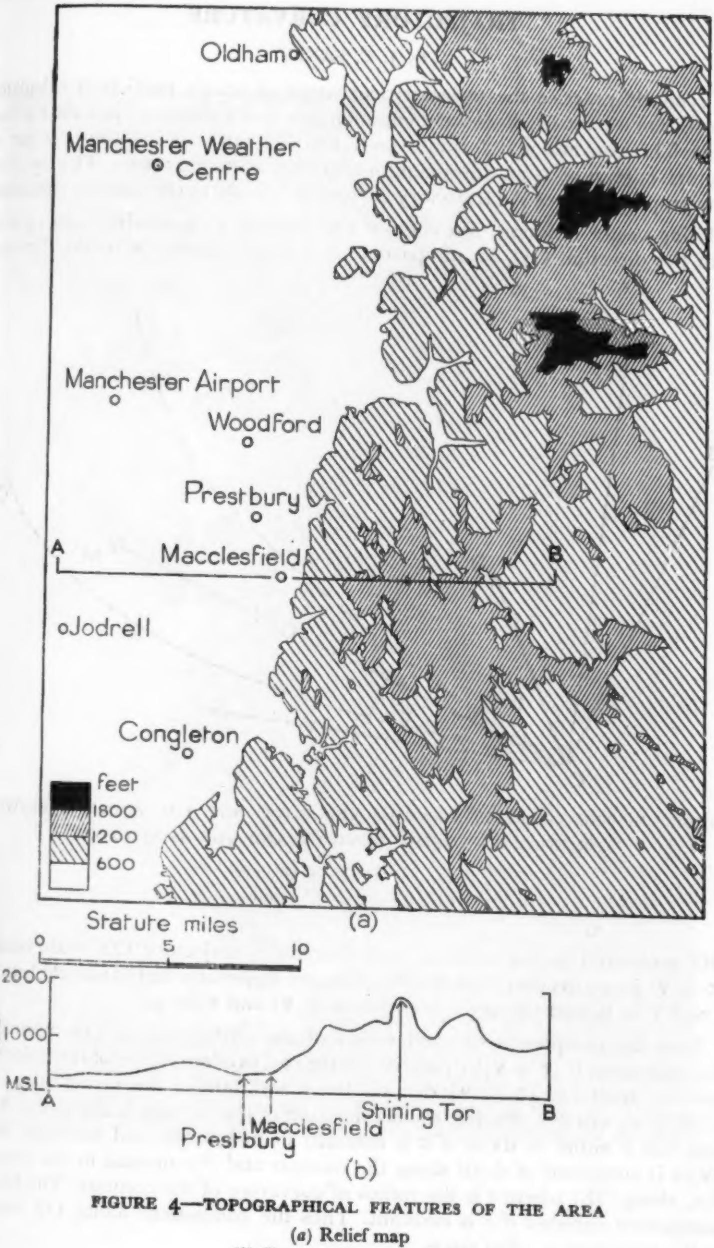

FIGURE 4—TOPOGRAPHICAL FEATURES OF THE AREA

(*a*) Relief map

(*b*) Cross-section through AB

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TRAJECTORY CURVATURE

By J. C. SAXBY

In synoptic practice the trajectory curvature of an air particle is calculated in order to use the gradient wind equation as a better estimate than the geostrophic. The conventional formula used for this purpose involves the use of contour curvature as an approximation to streamline curvature. The equation now proposed relates the trajectory curvature directly to the contour curvature.

Using vector notation, if a contour OC (Figure 1) is moving with velocity $\mathbf{c}$ in the direction OD, an air particle at O with velocity $\mathbf{v}$ in the direction

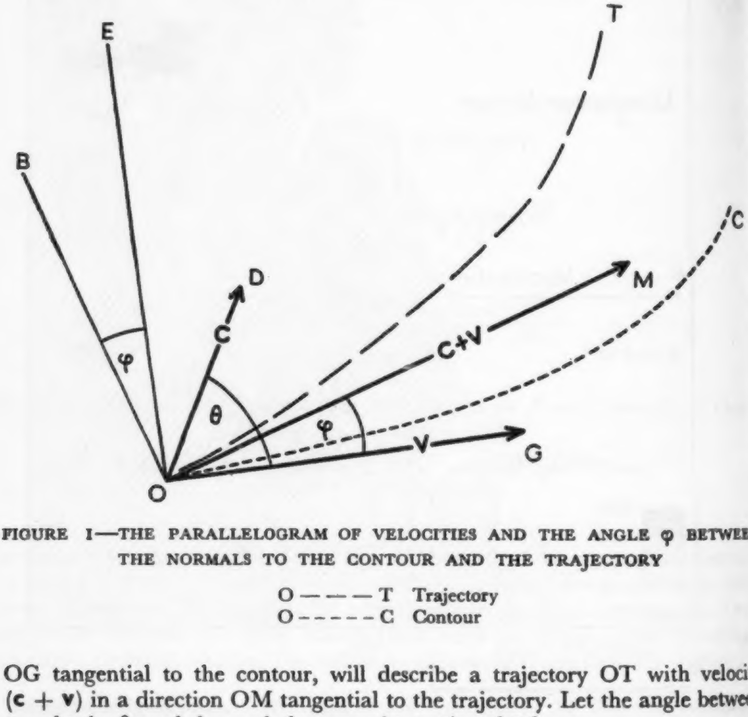


FIGURE 1—THE PARALLELOGRAM OF VELOCITIES AND THE ANGLE φ BETWEEN THE NORMALS TO THE CONTOUR AND THE TRAJECTORY

O — — — T Trajectory
O - - - - - C Contour

OG tangential to the contour, will describe a trajectory OT with velocity $(\mathbf{c} + \mathbf{v})$ in a direction OM tangential to the trajectory. Let the angle between $\mathbf{c}$ and $\mathbf{v}$ be θ, and the angle between $(\mathbf{c} + \mathbf{v})$ and $\mathbf{v}$ be φ.

Now the component of acceleration of the particle along OB, normal to the trajectory, is $|\mathbf{c} + \mathbf{v}|^2/r'$, where r' is the radius of curvature of the trajectory, and the modulus $|\mathbf{c} + \mathbf{v}|$ denotes the magnitude of the vector sum, i.e. $\sqrt{(c^2 + 2vc \cos\theta + v^2)}$. But the acceleration of the particle is also $\mathrm{d}(\mathbf{c} + \mathbf{v})/\mathrm{d}t$ and this is equal to $\mathrm{d}\mathbf{v}/\mathrm{d}t$ if $\mathbf{c}$ is constant in magnitude and direction. Now, $\mathrm{d}\mathbf{v}/\mathrm{d}t$ is composed of $\mathrm{d}v/\mathrm{d}t$ along the contour and v^2/r normal to the contour, (i.e. along OE) where r is the radius of curvature of the contour. The former component vanishes if v is constant. Thus the component along OB normal to the trajectory is $(v^2/r)\cos\varphi$.

Photograph by Michael Fairclough

PLATE I—DAMAGE CAUSED BY THE TORNADO IN THE VALE OF YORK ON 25 JUNE 1963

See page 366

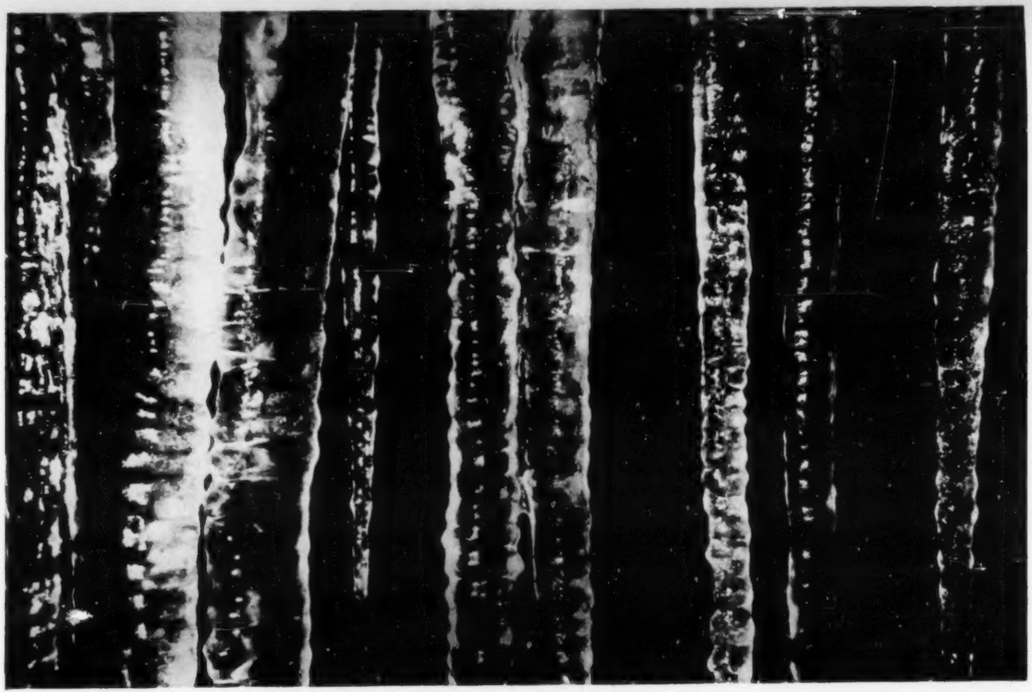
Photograph by Michael Fairclough

PLATE II—DAMAGE CAUSED BY THE TORNADO IN THE VALE OF YORK ON 25 JUNE 1963

See page 366

PLATE II—DAMAGE CAUSED BY THE TORNADO IN THE VALE OF YORK ON 25 JUNE 1963

See page 366



Photograph by M. M. Woods

PLATE III—ICICLES PHOTOGRAPHED ON THE EVENING OF 24 JANUARY 1963

Electronic flash was used to take this photograph through an open fanlight. The icicles, hanging from the roof guttering, were about three feet long.

To face p. 365

Photograph by R. K. Pilsbury

PLATE IV—THREE STAGES IN THE LIFE OF A FUNNEL CLOUD AT BRACKNELL ON 2 SEPTEMBER 1963

The photographs were taken (from left to right) at 1228, 1230 and 1236 GMT. The funnel cloud was observed in the unstable air near the centre of a shallow depression which moved over Bracknell on 2 September 1963. The depression was first located as a tropical storm (BEULAH) near the Windward Islands on 21 August.

Therefore $|\mathbf{c} + \mathbf{v}|^2/r' = (v^2/r) \cos \varphi,$ ...(1)

and hence $$\frac{r}{r'} = \frac{v^2}{|\mathbf{c} + \mathbf{v}|^2} \cos \varphi. \qquad \text{...(2)}$$

By projecting OM along OG we have, since GM = OD

$$|\mathbf{c} + \mathbf{v}| \cos \varphi = v + c \cos \theta. \qquad \text{...(3)}$$

Eliminating cos φ from equations (2) and (3)

$$\frac{r}{r'} = \frac{v^2 \, (v + c \cos \theta)}{|\mathbf{c} + \mathbf{v}|^3}. \qquad \text{...(4)}$$

The magnitude of the geostrophic wind G can be written, using vector notation,

$$G = |\mathbf{c} + \mathbf{v}| \pm \frac{|\mathbf{c} + \mathbf{v}|^2}{fr'}, \qquad \text{...(5)}$$

where f is the Coriolis parameter.

Using equation (4) this becomes

$$G = |\mathbf{c} + \mathbf{v}| \pm \frac{v^2 \, (v + c \cos \theta)}{fr \, |\mathbf{c} + \mathbf{v}|}, \qquad \text{...(6)}$$

from which tables of correction to geostrophic wind can be computed conveniently (using + sign for cyclonic curvature). The corrections are compared in Tables I and II with those recently[1] computed from the conventional formula where allowance is also made for movement of contours.

TABLE I—EXAMPLES OF CORRECTIONS TO GEOSTROPHIC WINDS FOR CONTOURS WITH CYCLONIC CURVATURE AND IN LATITUDE 50 DEGREES

G	c	θ	r	Correction	Conventional correction
knots	*knots*	*degrees*	*n. miles*	*knots*	*knots*
80	35	150	1000	−20	−15
95	15	10	500	−18	−21
130	25	145	500	−49	−45
140	30	60	1000	−24	−27
160	20	60	500	−49	−52
185	30	0	1000	−36	−41

TABLE II—EXAMPLES OF CORRECTIONS TO GEOSTROPHIC WINDS FOR CONTOURS WITH ANTICYCLONIC CURVATURE AND IN LATITUDE 50 DEGREES

G	c	θ	r	Correction	Conventional correction
knots	*knots*	*degrees*	*n. miles*	*knots*	*knots*
25	10	60	900	1	2
40	20	30	900	1	3
40	35	150	1000	20	10
65	15	10	900	10	15
90	30	0	1000	12	24
95	30	60	1000	24	43

Acknowledgement.—Acknowledgement is made to Dr. J. Pepper for detailed and critical comments on earlier drafts.

REFERENCE

1. Meteorological Office. Gradient wind tables. Unpublished, 1962.

551.515.32:551.556.1

A TORNADO IN THE VALE OF YORK ON 25 JUNE 1963

By J. HOUSEMAN

At about 1500 GMT on the grey, rainy afternoon of 25 June 1963 a disturbance, popularly described as a 'freak whirlwind,' crossed the town of Thirsk, in the Vale of York, from south to north leaving a narrow trail of damage behind.

One man was injured when he was lifted into the air and thrown against a wall about ten yards away, but otherwise damage was confined mainly to buildings and trees. Several trees were blown down, most of them falling towards the north-east; others had branches, even large limbs, torn off. One had the whole top removed, a little above the main fork in the trunk, some ten feet above the ground. The splintered ends of the torn branches distinctly show that they were twisted off. Numerous roofs were holed, slates and tiles being scattered in all directions and even heavy ridge stones thrown down. One outhouse roof was lifted, turned back to front and then replaced on its supporting walls. Part of a gable end was torn out and, in the cemetery, several gravestones were uprooted and moved for distances of up to fifty yards.

The trail of damage was about a mile long, slightly curved, with a mean direction of 350 degrees. It is difficult to estimate the width as the damage was intermittent, some objects apparently in direct line being untouched. At one point a gap 15 yards wide was made through a shelter belt of trees but, as this belt is at an angle to the line of damage the actual width of the trail is calculated at between 5 and 10 yards only. The direction of motion was from the southern edge of the town to the north-western edge. The initial development and final disappearance of the disturbance, both of which occurred in open country, were not observed (see Plates I and II).

Eyewitnesses described the phenomenon as a 'black cone' making a loud noise and this description, coupled with the character of the damage, shows fairly definitely that the disturbance was a tornado, though apparently only a small one.

No thunder was observed but there was a period of very heavy rain at the time of the passage of the tornado. The total rainfall recorded for the day at Thirsk Grammar School, which was the first building to be damaged, was 16.3 millimetres, but it is not known how much of that fell at the appropriate time. However at the Meteorological Office at Royal Air Force, Topcliffe, some two miles south-west of the school, 10 millimetres fell in the forty minutes between 1430 and 1510 GMT. When this heavy fall began rain had already been continuous for seven hours; afterwards it became slight and intermittent.

No tornado was seen from Topcliffe and there was no wind at all at the time. Earlier the wind had been blowing from 130 degrees at 10 to 15 knots and later it gradually picked up again to 10 to 15 knots from the south-west, veering north-west between 1600 and 1700 GMT. Autographic instruments recorded a sudden fall of pressure of one millibar at 1530 GMT accompanied by a temperature rise of nearly two degrees Celsius and a drop in humidity.

The synoptic charts for that day show a depression off north-west Scotland and a vigorous secondary moving north-eastwards across England. The tip of the warm sector of this secondary appears to have crossed the Thirsk area between 1500 and 1600 GMT the lowest observed pressure being 987 millibars.

The tornado seems to have formed in the unstable warm air, near the tip of the warm sector and just ahead of the depression centre, a position which Lamb[1] has stated as being a favoured situation for tornado formation.

REFERENCE

1. LAMB, H. H.; Tornadoes of May 21, 1950. *Met. Mag., London*, **79**, 1950, p. 245.

551.515.827:551.555.4

KATABATIC WINDS AT ACKLINGTON DURING A VERY COLD SPELL

By J. B. McGINNIGLE

During the period from 22 February 1963 until 4 March 1963, exceptionally large diurnal temperature ranges were reported in most parts of England. At Acklington, Northumberland, diurnal ranges of 12 to 16°C were noted in association with cloudless conditions and a completely snow covered ground surface. Throughout the period a katabatic wind was recorded every night.

Synoptic situation.—The synoptic situation was remarkably repetitive during the investigation period. Anticyclonic centres were maintained over Europe and Scandinavia, with intense depressions tracking south-west to north-east over the Atlantic to become slow moving in the Atlantic somewhere west or south-west of Iceland. The frontal systems associated with these depressions progressed quickly eastwards to become slow moving near Ireland.

During the period, five such systems moved in from the Atlantic. The first four became slow moving over or to the west of Ireland, each one frontolysing a little further east than the last in the following positions: 15°W (1800 GMT 24 February); 13°W (1200 GMT 27 February); 12°W (0001 GMT 1 March) and 8°W (1800 GMT 3 March). The final system moved across north-eastern England at 1800 GMT on 4 March, when the anticyclonic system, by this time over Germany, had sufficiently decayed.

The upper air structure, taken from the Aughton upper air ascents showed a typical anticyclonic, subsiding air mass. At 0001 GMT on 23 February, the subsidence inversion was 2°C in the layer 790–750 mb, the air from the surface to the inversion showing conditional instability. The air was appreciably drier above the inversion. The inversion gradually lowered and the air became drier until at 0001 GMT on 2 March, the time of maximum anticyclonic development, the base of the inversion had lowered to 1000 mb. Thereafter the anticyclonic decay showed on the ascents as a gradual cooling and moistening between 1000 and 500 mb. The anticyclonic situation was responsible for the existence of exceptional cloudless conditions over the investigation period. Of the total number of observations considered, only 12.2 per cent reported cloud below 25,000 feet.

Situation and topography.—Acklington—position 55°18′N 01°38′W, and 138 feet above mean sea level—is situated 3 miles west of the Northumberland coast in north-east England and about 1 mile south-east of the course of the River Coquet. Figure 1 shows the significant topography of the area. The ground rises slowly to the west, reaching a maximum of 1447 feet at Tosson Hill, some 13 miles away, while the Cheviot Hills, 22 miles north-west of

Acklington, rise to a maximum of 2576 feet. The source region and upper reaches of the River Coquet lie in the valley between the Cheviots and Tosson Hill.

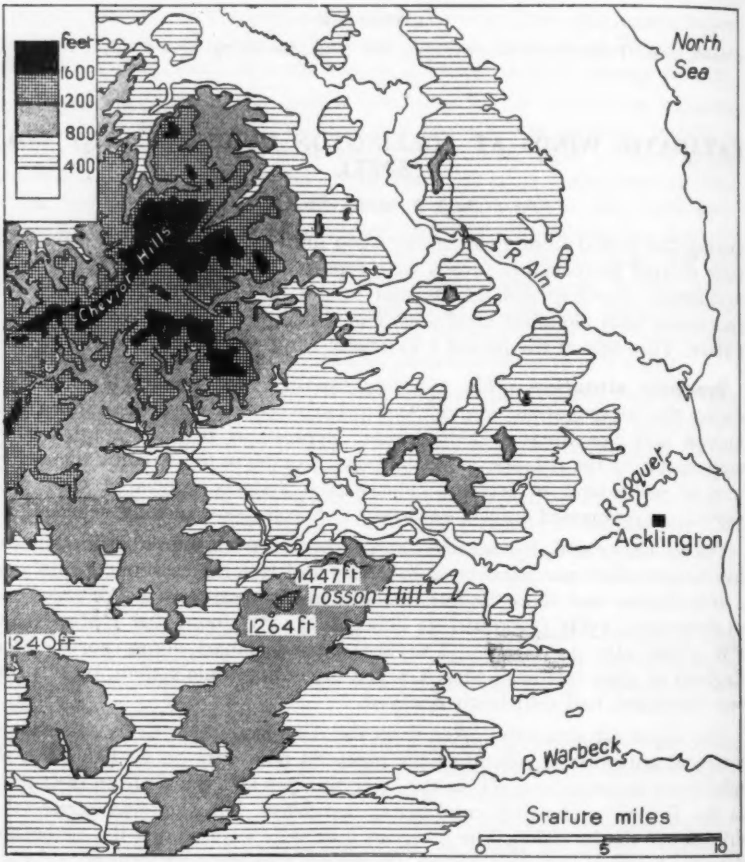


FIGURE 1—RELIEF MAP OF THE ACKLINGTON AREA

Observational data.—The period of investigation commenced at 1800 GMT on 22 February 1963 and continued until 1500 GMT on 4 March 1963. Continuous hourly observations were taken over the period, producing a total of 238.

The wind speed and direction, and air temperature for each hour were plotted for each day as in Figure 2, using a common time-axis. The gradient wind speed and direction was estimated to the nearest 5 knots and 10 degrees, using the geostrophic wind obtained from six-hourly surface synoptic charts and, where necessary, applying a correction evaluated from the gradient wind equation. The calculated wind was then checked as far as possible with the actual wind between 2000 and 3000 feet taken from the Aughton ascent.

The gradient wind so obtained was superimposed on the surface wind diagram as in Figure 2. Sunrise and sunset times were noted on the time axis.

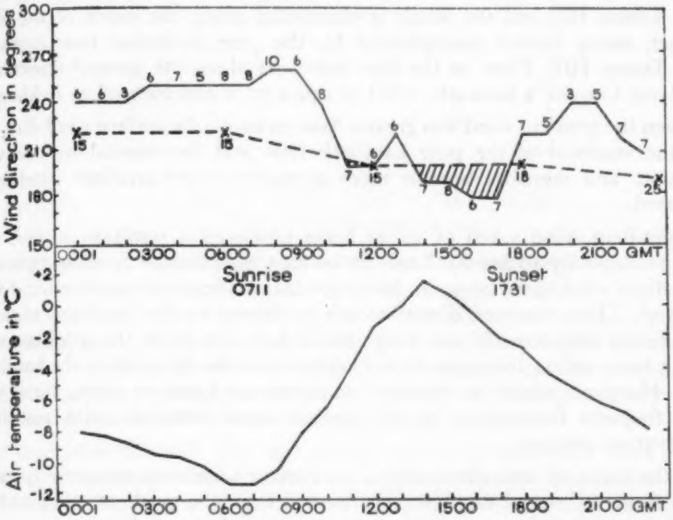


FIGURE 2—SURFACE WIND DIRECTION AND SPEED, TEMPERATURES AND ESTIMATED GRADIENT WIND ON 24 FEBRUARY 1963

In wind diagram: ———— surface wind — — — gradient wind

The figures plotted against the surface wind curve are the wind speeds recorded at that time, figures on the gradient curve are estimated speeds in knots.

Any surface wind which was veered 10° or more from the gradient wind direction was considered to be katabatic or the resultant of a katabatic flow and a normal surface wind. The onset of such a flow was always accompanied by a marked fall in air temperature, often representing the largest temperature fall of the night. Clear sky conditions were experienced throughout almost the whole period and this, with a full snow cover, was responsible for very large diurnal temperature ranges. The temperature graph in Figure 2 is typical. In addition, the observed katabatic winds were noted to be subject to fluctuation of the type which can be seen from Figure 2 during the hours 0900 to 1400 GMT. At 1100 and 1200 GMT, the katabatic wind was replaced by a surface wind of 200°. The shaded portion of the diagram shows the only time when the surface wind was not influenced by a katabatic flow.

Direction and fluctuation of the katabatic flow.—Throughout the period of investigation, a katabatic wind flow was observed every night. Of the 238 observations studied, 133 were undoubtedly katabatic winds or winds into which a katabatic component had been introduced. This figure represents 55·9 per cent of the total.

When the gradient wind was calm or south to south-westerly, less than 15 knots, the katabatic flow was from 240–270°, with a speed of 5–10 knots. This is the normal direction from which a pure katabatic flow is reported at Acklington and the following mechanism is suggested: after sunset (varying from 1729

to 1748 GMT over the period), rapid cooling takes place on the slopes of the Cheviots and on Tosson Hill, and a katabatic flow commences. The air flowing south and south-eastwards from the Cheviots joins with the air flowing north from Tosson Hill and the whole is channelled along the valley of the River Coquet, being further strengthened by the pure katabatic flow eastwards from Tosson Hill. Thus, as the flow continues along the general direction of the River Coquet, a katabatic wind of 240–270° is experienced at Acklington.

When the gradient wind was greater than 20 knots, the surface wind direction was the resultant of the pure katabatic flow and the normal surface wind direction, and therefore became more southerly as the gradient wind speed increased.

A gradient wind speed of 20–30 knots produced a resultant surface flow from 210–240° (5–10 knots). This can be seen from Figure 2, 1800–2300 GMT. A gradient wind speed of 35–40 knots produced a resultant surface wind from 190–210°. These observed directions are confirmed by the resultants obtained from vector diagrams. It was a significant fact that when the gradient wind was 15 knots or less, there was little fluctuation in the direction of the katabatic wind. However, when the gradient wind was 20 knots or more, there were more frequent fluctuations in the surface wind direction, with associated temperature changes.

At the times of such fluctuations, the surface wind was temporarily established from its normal direction, i.e. backed from the gradient wind and the loss of the cold katabatic airflow resulted in a rapid rise of air temperature. An example of this can be seen in Figure 2 at 1000–1100 GMT where the interruption of the katabatic flow is linked with a very sharp rise in temperature.

The interruption of the katabatic flow is thought to be due to the complex flow which must exist as a result of katabatic effects on all slopes. At times the combined katabatic forces at a location are likely to balance out and permit a break-through of the normal surface wind at a point which was previously affected by a katabatic wind. This effect has been fully studied at a different location in an earlier paper.[1]

Onset of katabatic flow.—The onset times of the katabatic flow were estimated to the nearest half hour and the conditions at these times noted. On 7 out of the 10 occasions, a non-fluctuating flow was observed, whereas, on the other 3, the katabatic flow was disturbed at first for 2–4 hours before becoming steady. Onset times varied from 1730 to 0200 GMT.

On each occasion of similar gradient wind speed, the steady katabatic flow (whether or not preceded by a fluctuating period) commenced at a very similar temperature. These temperatures can be seen plotted on Figure 3. The temperature at which the katabatic fluctuations commenced was also plotted in relation to its gradient wind speed. It is to be noted that no fluctuation took place at the time of onset when the gradient wind speed was less than 20 knots.

Cessation of katabatic flow.—The katabatic flow ceased between 0730 and 1330 GMT at temperatures ranging from –8.6°C to +1.8°C. There was however no apparent correlation between cessation temperatures and gradient wind speeds. It was noted that the greatest temperature rises were associated with the periods of greatest fluctuation.

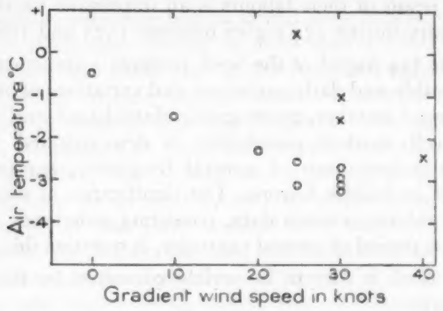


FIGURE 3—AIR TEMPERATURE AND THE ONSET OF THE KATABATIC FLOW

o Steady flow onset x Fluctuating flow onset

The gradient wind direction was 180–210°

Conclusions.—During a 10-day period of cloudless conditions, complete snow cover and large diurnal air temperature ranges, a katabatic wind, or a wind influenced by katabatic effects was recorded at Acklington every night. The speed of these winds was always in the range 5–10 knots.

At times, the katabatic flow was subject to fluctuations which were always reflected in the temperature curves. It is suggested that the fluctuations which only became frequent when gradient wind speed exceeded 20 knots are due to the complex katabatic flow which must take place in hilly regions.

REFERENCE

1. MCGINNIGLE, J. B.; Correlated fluctuations of wind direction and air temperature at Renfrew Airport on 12 October 1960. *Met. Mag., London*, **90**, 1961, p. 146.

REVIEWS

Nordlichtbeobachtungen in Ungarn (1523–1960), by A. Réthly and Z. Berkes, 7in. × 9½in., pp. 189, *illus.*, Akadémiai Kiadó, Budapest V, Alkotámny Utca 21. 1963. Price: $6.00.

The important task of searching the archives for records of aurorae in low latitudes in past centuries is not only arduous but presents formidable difficulties. Displays are so infrequent that observers are unfamiliar with the appearance and behaviour of the phenomenon. The low latitude aurora appears normally as a red glow on the poleward horizon, which may be quite unspectacular and so pass unrecorded unless it is exceptionally brilliant. Even in that case, it has often been mistaken for the reflection in the sky of a great fire and, indeed, it was responsible for unnecessary journeys northwards by fire engines in south-east Europe on several occasions as recently as the International Geophysical Year. Besides, descriptions of other phenomena, notably meteor occurrences, St. Elmo's Fire, crepuscular rays and unusually colourful sunsets may be confused with aurora. Sketches and paintings by observers provide the best evidence and some quite magnificent examples of these from the seventeenth and eighteenth centuries are reproduced in colour in this volume. The authors state that they have carefully checked the observations to eliminate cases of confusion with other phenomena; the earlier Hungarian observations were examined along with those in the well known catalogue of Fritz (1873) and the later data with records of sunspots and geomagnetic

disturbance. The result of their labours is an impressive catalogue of displays observed in Hungary during 224 nights between 1523 and 1960.

The second part (34 pages) of the book presents a statistical analysis of the data. Annual, monthly and daily variations and variations of auroral frequency with latitude, sunspot number, geomagnetic disturbance and temperature are determined. A well marked parallelism is demonstrated between curves showing the secular variations of auroral frequency, sunspot number and mean temperature in middle Europe. The significance of some of the results of this analysis of inhomogeneous data, consisting sometimes of as few as 117 observations over a period of several centuries, is questionable.

This attractive book is sure to be widely consulted by those interested in auroral morphology.

J. PATON

Meteorobiologie und Elektrizität der Atmosphäre, by R. Reiter. 9½in. × 6½in., pp.xii + 424, *illus.*,Akademische Verlagsgesellschaft, Geest & Portig K.-G., Leipzig, 1960. Price: D.M. 48.

This being a book of encyclopaedic scope and Teutonic thoroughness, any attempt at a full review would degenerate into a mere catalogue, and an incomplete one at that. However much of the book deals with the influence of weather on the onset of disease, and it soon becomes evident that the author's favourite meteorological factor is 'Infralangwellen'—infra-long waves—by which he means the radio waves emanating from electric discharges in thundery weather. But, since thunderstorms arise in an unstable atmosphere, there often seems to be some doubt whether the infra-long waves or other phenomena which accompany instability are the predominating factor.

The author's own work in this field appears to have started soon after the second world war. So the first medical condition he deals with is the pain from amputation stumps, including the 'phantom limb' sensation due to impulses caused to travel along nerves which formerly transmitted sensations from the missing limb to the spinal cord. In this case he finds that the intensity of pain is correlated with disturbances of the electrical field but not at all with the intensity of the infra-long waves; i.e. it is changes in the intensity of the latter that matter. Pain from brain injuries, on the other hand, is correlated with the intensity of the infra-long waves, but not with changes in their intensity.

Haemorrhages from the lung in tuberculous patients are 'weakly weather-conditioned,' but nevertheless there is a greater-than-random increase with 'unstable atmospheric layering, increased turbulence and cyclonic character,' —all of which are accompanied by increased production of infra-long waves—and also with Alpine föhn winds which penetrate to ground level. The onset of poliomyelitis, according to figures the author gives, is more probable in moist warm than in cold dry weather in the proportion of 119 : 91.

The section on disease ends with a discussion (pp. 170–173) on how all these results could be put to practical use in medical treatment, but amid much verbiage little emerges beyond a suggestion that observation of the weather might enable doctors in sanatoriums to plan ahead for an abnormal influx of patients.

A section on the influence of the weather on the timing of births is of particular interest to the reviewer, who once had to attend these functions over the whole of Lambeth, from Blackfriars Bridge to Kennington Oval, with only one fellow-student to share the work, just as the returned soldiers from the first world war were starting up their families again. It soon became obvious that these events tended to come in bursts, a couple of days' and nights' furious cycling around in an attempt to cope, interspersed with two or three days of well earned (comparative) rest. There was a strong presumption that the weather had something to do with it, and we might have written a useful thesis if we had been, at that time, familiar with stability and instability as meteorological terms. Dr. Reiter, anyway, has found a definite correlation. In Bavaria, during disturbed weather, the number of births per unit time was found to be 6 per cent higher in 'disturbed' than in 'undisturbed' weather. If an area 60–70 km in radius, centred on the weather observation point, was alone considered, the amplitude of the variation rose to 11.5 per cent. Unstable and cyclonic weather, turbulence, inbreak of moist warm air in summer, showers and thunderstorms, and even days of increased infra-long waves without cumulonimbus, were all accompanied by temporary increases in the birth rate. He gives figures of 2.3 per cent increase on the day after a cold front and 5 per cent increase when infra-long waves were at a maximum. The onset of deaths, the author says, is also more frequent at times of maximum infra-long waves, and vice versa.

There is much else of interest in the book, including the influence of weather on plants and animals and on accident proneness, the effects of solar eruptions, the therapeutic value of 'electro-aerosols,' etc. But its appearance at the onset of the Space Age poses a new problem, hitherto hardly foreseen: if minor fluctuations in our earth's environment are so disturbing to its human occupants how will they fare when they found colonies in the vastly different environments of other planets?

A. E. SLATER

Climatologie méthodes et pratiques, by H. Grisollet, B. Guilmet, and R. Arléry. 9¾in. × 6¼in., pp. ix + 401, *illus*. Gauthier-Villars & Cie Editeur, Quais de Grands-Augustins, 55, Paris VIe, France, 1962. Price: 50 NF.

This is a companion volume to Mesures en Météorologie,[1] both books forming part of a collection called Monographies de Météorologie published under the general editorship of A. Viaut, Director of the Météorologie Nationale.

It is an extremely well planned work, the subject unfolding itself with orderly precision as an attempt is made to deal with all its aspects. This admirable method has its dangers; it may cause undue emphasis on certain matters merely because they are part of the general scheme, which itself is so wide that to cover everything means stretching rather thinly here and there. But this is a danger of which the authors are well aware and they point out on the first page that the book is a guide rather than a treatise on climatology. It seems to me to occupy a good and useful average position.

It is certainly a good guide in the way it takes one in an articulate manner through the subject divided into three main parts. First, the basic notions of climatology: definition, agents, elements and dimensions of climates, observations and data and their treatment.

The second part, which the authors think is the most important, and which should certainly prove the most useful to the general meteorologist, deals with statistical methods. Conscious of the limitations already outlined, the authors steer a safe course between the rigorous treatment expected by specialist statisticians and the attitude of those experienced forecasters "...so conscious of the nature of continuous evolution of atmospheric phenomena and consequently inclined to study them from a determinist standpoint, that they might deem excessive the importance here given to the statistical approach." Here again the argument proceeds with such orderly sequence that it can be boarded at any stage by the non-specialist without strain. Classification and tabulation are followed by graphical representation and distributions; then the principal parameters for averaging, dispersal and shape, followed by the main forms of distribution, sampling, fit, and normals; then contingence and correlation, time series, periodicity, persistence and so on. This part ends up with a useful chapter on graphical representation of climatological data.

This exposition makes a very interesting contrast with our *Handbook of statistical methods in meteorology*,[2] that erudite pot-pourri which, a little awe inspiring at first—at any rate for the likes of me—gains on long browsing acquaintance, rather like a private collector's over-congested room. In the same vein, I might compare this book to a well indexed small public museum.

The third part, on applied climatology, is at once the most straightforward and the most controversial. The subject is first treated, very rapidly, from the meteorological aspect or contribution of climatology to the study of the causes of weather phenomena. There, confronted with a vast and difficult subject, the book is most like a guide. I would have liked to read some more about dynamic climatology, especially after the promising remarks on this subject in the introduction. Next the geographical aspect of climatology is given a fairly comprehensive and classical treatment, dealing with descriptive climatology and the various ways in which climates are currently classified. Finally, there is a chapter on "Aspect pratique de la climatologie appliquée," which I might translate as doubly applied climatology. This ranges, very rapidly perforce, over bioclimatology, including the human aspect, agroclimatology, hydrology, aviation meteorology, and various other practical applications, ending up with insurance risks assessments. Here a little more about developing operational research methods, especially from the United States, would have been in keeping with the generally well informed character of the book. But it must be remembered that development in this field is so rapid that, for instance, the important *Journal of Applied Meteorology* of the American Meteorological Society was not started in time (March 1962) to be included in the comprehensive list of books and periodicals given at the end of the book, where an index would also be very welcome.

I was surprised to see in Chapter VII that observations from aircraft were given as typical example of observations "non utilisable en climatologie."

Throughout the book expressions in English, German and Russian most commonly associated with certain concepts are used giving it a truly international character.

If he can cope with the language, it would be difficult to think of a more useful book for the applied meteorological analyst intrigued by the reiteration

of certain features on the charts which confront him daily, or in the weather in which he finds himself immersed when he has time to lift his head or even stroll outside. This excellent guide should have a place on his library shelf.

REFERENCES

1. PERLAT, A. and PETIT, M.; Mesures en Météorologie. Paris, Gauthier-Villers, 1961.
2. BROOKS, C.E.P. and CARRUTHERS, N.; Handbook of statistical methods in meteorology. London, HMSO, 1953.

J. COCHMÉ

NOTES AND NEWS

The Royal Meteorological Society's visit to Bracknell

A party of 30 Fellows of the Royal Meteorological Society visited Bracknell on Wednesday 12 June 1963 for the Society's 'Summer Visit'. The party saw the communications centre and the forecast office before being given talks by Mr. Coles and Mr. Bushby on the techniques of forecasting. On the fifth floor they watched the electronic computer rapidly produce a forecast for the 500 mb level, and then fill in what was left of the 10-minute programme time allotted with a spirited rendering of 'The Volga Boatmen'. After visiting laboratories in the High Atmosphere and Instrument Branches, the members of the party were taken to the Experimental Site where they had tea. Finally, they watched a radiosonde ascent, followed the telemetry reception and the radar tracking, and saw the sferics network in action.

R. FRITH

Meteorological Magazine: increase in price

We regret that owing to further increases in the cost of printing and publication it has become necessary to raise the price of the *Meteorological Magazine*. The price will be 3*s*. 0*d*. an issue with effect from the January 1964 number. The net annual subscription will become 39*s*. including postage. Present subscribers will remain on the existing rate until renewal of their subscriptions is due.

PUBLICATION RECEIVED

The Weather: Precipitation (in the series "Geography–meteorology"). 30 in. × 40 in., Wallchart (C 887) in two colours, Educational Productions Ltd., East Ardsley, Wakefield, Yorkshire, 1963. Price 10*s*.

LETTERS TO THE EDITOR

The sub-sun

May I make a few observations on the very interesting photograph of the sub-sun in *Meteorological Magazine*, Volume 92, page 254.

The brilliance of the reflection might lead one to suppose that, unless of course there was no cloud available, it would generate parhelia. Also there is another point. These may not have shown on the photograph, but it appears that, according to Visser (*Handbuch der Geophysik*, 8, 1961, p. 1038) that due to total reflection on the lower side of the plates, interference may occur giving rings round the image, (Figure 358, p. 1039 in the above volume and *Met. Z. Braunschweig*,55, 1938, p. 265). Also (p. 1035 in *Handbuch der Geophysik*) the sub-sun may, in the polar regions with a low sun, be seen from the ground. It was observed frequently at Maudheim; on August 17 1951, from the meteorological mast, it could be seen on the level snow.

Incidentally, in his recent entertaining work on the flying saucer mania, Dr. D. H. Menzel (*The world of flying saucers* by Menzel and Boyd Doubleday, New York, 1963) thinks the sub-sun is the source of many reports. He tells me privately it and its parhelia can, from a fast plane, perform amazing antics and deceive the unwary.

Rockmount Hotel, Tunbridge Wells, Kent. CICELY M. BOTLEY

Reply from Mr. G. J. Jefferson:

The sub-sun was visible for about 15–20 minutes (which in a Boeing 707 means 120–150 nautical miles), the photograph being taken towards the end of this period when, as can be seen in the photograph, the cirrus was beginning to thin out. During the period of observation I did not see any parhelia generated by the sub-sun. I do not think there were any, though I cannot be absolutely certain about this since the angle of vision may possibly not have been wide enough to observe them. The aircraft windows were about 12 inches wide and glazed with three layers of perspex separated by gaps of an inch or so. On one side parhelia could have been hidden by the wing of the aircraft. There was no sign of any coloured bands or fringing round the sub-sun which was quite white.

Meteorological Office, London (Heathrow) Airport.

Funnel cloud observations at Bracknell

The following is an account of observations taken between 1225 and 1300 GMT from the Meteorological Office roof, Bracknell, on Monday, 2 September 1963:

1225 GMT: A large intense black cloud covered approximately half the sky, from SE to NW, through SW, and up to the zenith. Precipitation was seen falling heavily in the distance, from the more central parts of the cloud. The rest of the sky was covered with much smaller and less significant clouds, with small patches of blue sky between them. Between 1225 and 1300, the main cloud slowly but steadily approached, and also shifted somewhat to the right, but small patches of blue sky continued to be visible in the NE part of the sky. The area of heavy precipitation also shifted with the general movement of the cloud, and the nearest part of it was within a mile or two of the Meteorological Office between 1245 and 1300, during which time the main cloud covered most of the sky, including all the sky overhead. Continuous but slight rain fell at the Office between 1245 and 1300. A funnel cloud was seen in the NW at 1225, reaching about half way down to the ground, from the extreme right-hand part of the base of the main cloud, which in that vicinity was only shallow, and not very dark, the cloud base being about 10° in elevation there. During the next 10 minutes, the funnel cloud fluctuated somewhat in length and thickness, but did not alter materially until 1235, when it shrank fairly quickly to about half its original length, and then continued with little change until 1300. It also retained the same azimuth and elevation, so far as I could tell.

1235 GMT: Activity began to take place in the WSW, with a chaotic turmoil in some ragged clouds just below the main base level of the cloud, at an eleva-

tion of about 30°, and this effect was more or less continuous until 1300, though by that time, the centre of turmoil was in the W, at an elevation of about 45°. When this swirling turmoil had been underway for a minute or two, an object like a plume of smoke was seen rising quite quickly (while also fluctuating in intensity) from a point on the ground about a mile away. This happened simultaneously with the appearance, between it and the swirling cloud-base, of ragged shreds of cloud, which seemed to change shape and vertical position very rapidly, besides disappearing and reappearing with equal rapidity. But after perhaps another minute, there was a complete link-up from cloud to ground, which only lasted for a fraction of a minute, but long enough to see that the tornado vortex was moving slowly but visibly towards the right. Immediately afterwards, the vortex (which had been only pencil-thin at the ground) dissolved rapidly, and by 1240 it had completely vanished, leaving only the turbulent swirling motion in the base of the cloud, from which I saw the funnel cloud extend a short way downwards from the base of the cloud once or twice between 1240 and 1300. However, I was told that at 1250 the vortex had extended to the ground again for a short time, though I did not see this myself as I was away fetching a raincoat for those few minutes. The tornado that I saw briefly at about 1238 was in front and somewhat to the right of the heaviest precipitation, while the funnel cloud in the NW must have been well clear of any precipitation. There were a few not very loud rumbles of thunder between 1240 and some time after 1300.

Meteorological Office, Bracknell E.C.W.GOLDIE

[See Plate IV opposite page 365 for photographs of the funnel cloud. Ed. M.M.]

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